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US ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 507

THE PHYSIOLOGICAL RESPONSES OF MEN WEARING CHEMICALLY IMPREGNATED PROTECTIVE CLOTHING IN A HOT DRY CLIMATE

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Medical Problems of Field Operations
Task 17
Environmental Medicine
USAMRL Project No. 6X64-12-001

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Report No. 507
USAMRL Project No. 6X64-12-001-17

ABSTRACT

THE PHYSIOLOGICAL RESPONSES OF MEN WEARING CHEMICALLY IMPREGNATED PROTECTIVE CLOTHING IN A HOT DRY CLIMATE

OBJECT

To determine whether or not and to what extent a group of combat equipped soldiers wearing Hycar Absorbent Protective Underwear and XXCC3 Impregnated Fatigues can tolerate a hot dry climate under field conditions.

RESULTS

The rise in rectal temperature, increase in pulse rate, sweat output, and the dermatological status of a heat-acclimatized group of subjects wearing chemically impregnated clothing while doing a program of planned activity did not differ significantly from a control group.

CONCLUSIONS

In a hot dry climate, Hycar Absorbent Protective Underwear and XXCC3 Impregnated Fatigues are well tolerated by heat-acclimatized soldiers performing a moderate work load.

RECOMMENDATIONS

The effects of this protective clothing on the physiology of men in a hot humid climate and the effects produced in non-heat acclimatized men in both hot humid and hot dry climates should be investigated.

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THE PHYSIOLOGICAL RESPONSES OF MEN WEARING CHEMICALLY IMPREGNATED PROTECTIVE CLOTHING IN A HOT DRY CLIMATE

I. INTRODUCTION

The creation of a protective military uniform which would provide optimum protection against thermal radiation resulting from atomic explosions and from vapors, liquids, dusts, and aerosols of CBR agents is a project of paramount importance to the United States Army (1). The physiological problems associated with the performance of men in a hot environment are well recognized (2, 3, 4, 8). The additional problems created by the wearing of a protective uniform in hot environments have been anticipated (5). Preliminary studies (6, 7) have indicated that the heat load imposed while wearing chemically impregnated clothing can be physiologically tolerated. A well-controlled field study of a sufficiently large group of subjects wearing such clothing in a hot dry environment has not been performed. For this investigation, Hycar Absorbent Protective Underwear and XXCC3 Impregnated Fatigues were the protective uniform tested.

II. METHODS

Forty volunteer subjects[1] were studied at Dugway Proving Ground, Dugway, Utah, from 17 July to 21 July 1961. The subjects had a preliminary medical evaluation to eliminate those with cardiovascular disorders and obesity. The age range of the subjects was 18 to 25 years. All were Caucasian with the exception of two Negroes and one Oriental in the experimental group and four Negroes in the control group. All men had been stationed at Dugway for at least two months immediately preceding the beginning of the study and had recently participated in rigorous field maneuvers in the area. Heat acclimatization was judged to exist on this basis.

Twenty of the subjects served as a control group and were dressed in standard long underwear with a standard army fatigue uniform. Twenty men were the experimental group and wore Hycar Absorbent Protective Underwear and XXCC3 Impregnated Fatigues (90% polyethyl acrylate and 10% zinc oxide).

[1]Personnel from the 45th Chemical Company (control group), 46th Chemical Company (experimental group) plus six volunteers from the 266th Decontamination Platoon, 2nd Chemical Battalion.

CLOTHING LIST

Control Group	Experimental Group
Standard Fatigue Uniform	XXCC3 Impregnated Fatigue Uniform
Standard Long Underwear	Hycar Absorbent Protective Underwear
Fatigue Cap	Fatigue Cap
Cotton Socks	Cotton Socks
Combat Boots	Combat Boots
Pistol Belt	Pistol Belt
Canteen	Canteen
Carbine (Day 3 only)	Carbine (Day 3 only)
20 Pound Pack (Day 2 only)	20 Pound Pack (Day 2 only)

All uniforms were worn open at the neck and without gas mask or hood.

Both groups were subjected to several types of physical exertion which were selected to approximate activities of a soldier in the field. Physiological measurements were used to evaluate the degree of heat stress. Rectal temperatures were measured every 30 minutes with individual clinical glass rectal thermometers. Pulse rates were secured by auscultation of the heart with a clinical stethoscope applied to the left chest wall at thirty-minute intervals. Water intake and urinary output were measured throughout each experimental day. Subjects were weighed nude at the beginning and at the end of each day at which time a clinical evaluation of the condition of the skin was done. Meteorological data was obtained hourly.

On day one, the subjects rested in the sun for one hour and engaged in close order drill for the next two hours.

On day two, the men marched a ten mile road course with ten-minute breaks every half hour. This took seven hours.

On day three, the groups made two simulated combat approaches of a hill two hundred feet in vertical elevation. They crossed a valley, assaulted the hill (rushing up a thirty to forty degree grade to the top), and returned to base camp. Each assault took three hours.

On the fourth and final day, load moving tasks were performed. The men cleared an area of low vegetation with shovels and picks and moved eight to ten foot sections of telephone poles, for a total time of three hours.

During the four test days, the following criteria were utilized to remove a man from the study: 1) rectal temperature exceeding 104°F; 2) apical heart rate exceeding 180 beats/minute; 3) severe clinical symptoms due to heat of an incapacitating nature; and 4) decision by the subject that he could or would no longer continue in the study (including psychological cause).

III. RESULTS

Figure 1 illustrates the increase in rectal temperature that occurred during each period of activity. Each bar reflects the change from the basal temperature to the highest temperature encountered during that period of activity. Day two and day three are divided into before and after noon meal periods. There was no difference in rectal temperature between the experimental and control groups for any given day.

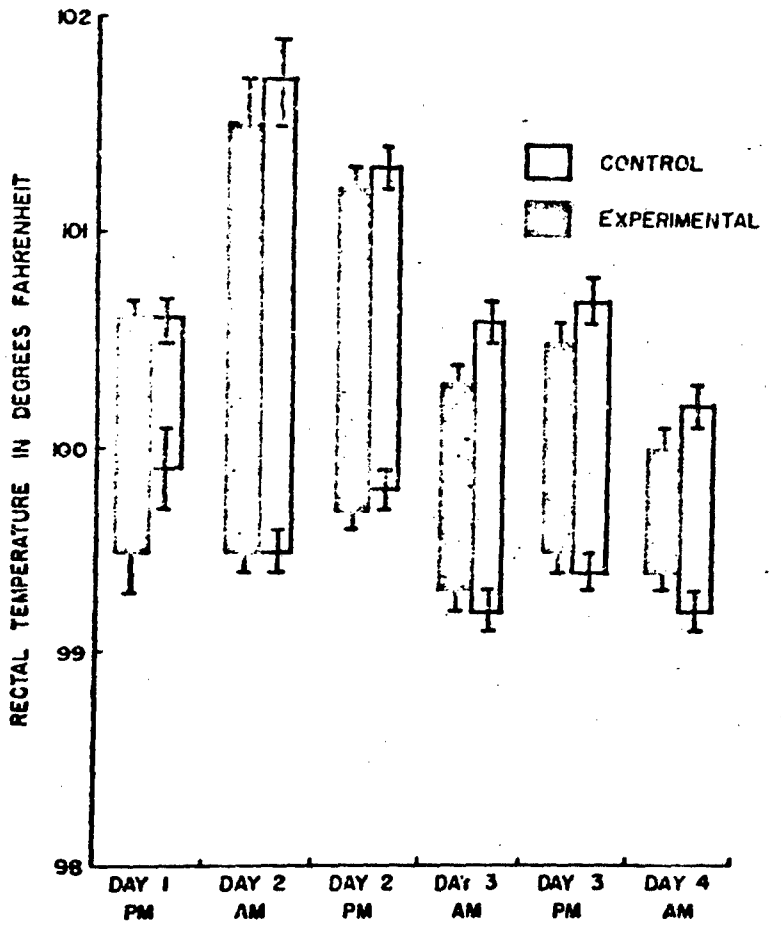

Fig. 1. The change in rectal temperature during the phases of programmed activity. The lower value of each bar represents the mean base line temperature of each group while the higher value represents the mean highest elevation of each group for any given period. One standard error of the mean is plotted as a vertical bar above and below the group mean values.

Figure 2 reflects the change in pulse rate from the basal level to th highest rate achieved during the different periods. No significant difference in heart rate was found between the two groups on any given day.

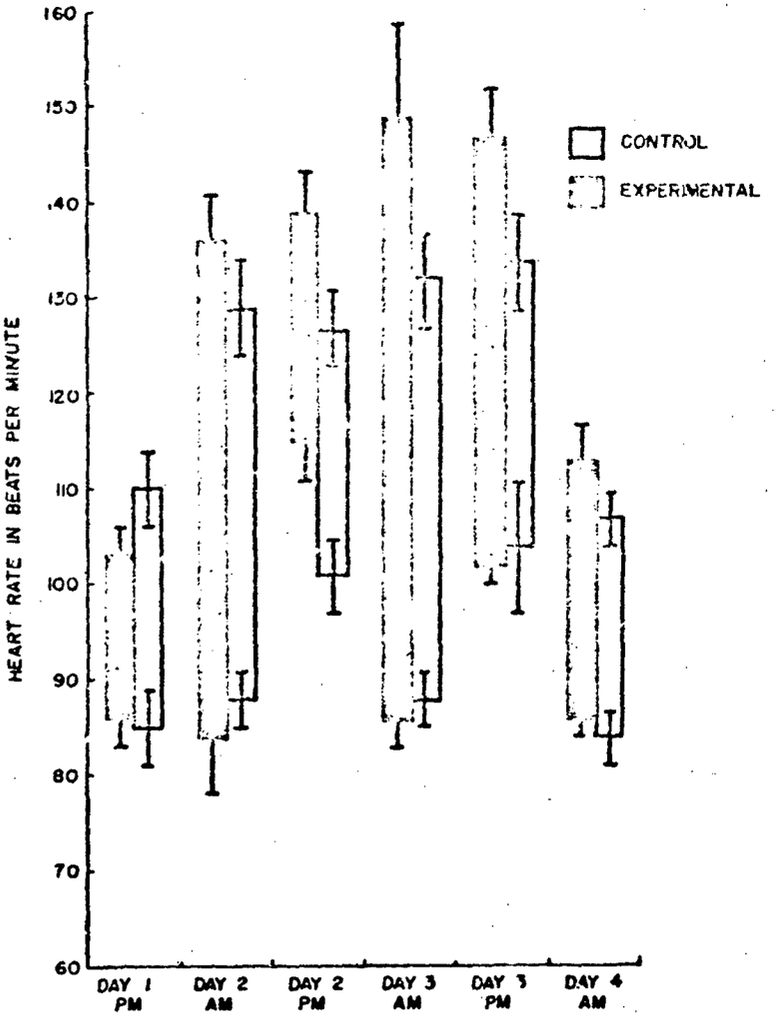

Fig. 2. The change in pulse rate encountered during the phases of programmed activity. The lower value of each bar represents the mean base line pulse rate of each group while the higher value represents the mean highest elevation of each group for any given period. One standard error of the mean is plotted as a vertical bar above and below the group mean values.

Figure 3 shows the sweat and respiratory water loss of each group in liters/test period. These values were calculated from the algebraic

sum of the weight change and fluid balance during each test period. Assuming respiratory water loss to be a constant, any difference between groups should reflect a change in sweat loss. The time for which these measurements were recorded differs from day to day. No significant difference is found between the two groups for any given test period.

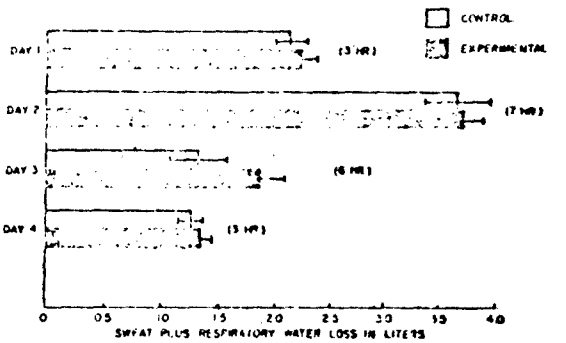

Fig. 3. Total sweat and respiratory water loss in liters during each test period of the study. Figures in brackets represent the total time involved in measurement on each day.

Table 1 lists the meteorological data. Each value represents an average of either three or four hourly measurements. The high black bulb temperatures and low relative humidity were the crucial factors in producing a rapid evaporation rate so that at no time did sweat appear on the outer garments of any of the subjects.

Table 1. Meteorological data recorded for the four day study. The WBGT index is computed as 0.7 of the wet bulb temperature, 0.2 of the black bulb temperature, and 0.1 of the dry bulb temperature (9).

METEOROLOGICAL DATA						
DAY	TIME	°F Black Bulb	°F Wet Bulb	°F Dry Bulb	% Relative Humidity	WBGT
1	PM	117.3	60.6	93.9	16.0	75.3
2	AM	114.4	60.0	88.3	19.0	73.7
2	PM	113.5	61.1	95.8	15.0	75.0
3	AM	108.6	58.7	84.0	22.4	71.2
3	PM	116.9	57.1	87.4	14.6	72.0
4	AM	118.5	58.2	83.3	22.0	72.7

Six subjects were dropped from the experiment. Five of these were for motivational reasons not related to heat. One drop out occurred at the onset of the first day, two at the onset of the third day, and two at the onset of the fourth day. Two were control subjects and three were experimental. One control subject was dropped during the morning of the second day for symptoms of heat intolerance (dizziness and nausea) without significant elevation of pulse or rectal temperature. Therefore, the data reported is based upon seventeen men in each group.

Dermatological examination revealed irritations equally in both groups in the areas of tight fitting clothing. One case of axillary miliaria rubra was found in the experimental group. It is quite possible that additional dermatological problems would have occurred had the uniform been worn for a longer period of time.

IV. DISCUSSION

Results of this experiment show that chemically impregnated protective clothing causes no abnormal physiological distrubance in a hot dry climate. For the type of activity in the study, there was no significant physiological difference between the two groups.

Higher rectal temperatures were recorded on the day of the road march than on the other days. This would agree with an assumption that long-term heat stress will cause a greater increase in rectal temperature than in pulse rate. The first half of the march involved a gradual ascent of approximately six hundred feet elevation. The highest temperatures were noted at this time.

The terrain of the hill assaulted on the third day caused brief but very intense physical exertion during the rush to the top. The very high pulse rate reflects the intensity of the work and the moderate increase in rectal temperature is probably due to the short duration of the assault.

The load moving tasks appeared to be about the least stressful considering the variables measured.

No comparisons among types of exercise can be made from the daily sweat loss calculations because of the time variable. It is interesting to note, however, that the greatest losses occurred in the same days that the highest rectal temperatures were recorded, a finding in agreement with previous work (10).

V. SUMMARY

The rectal temperature, pulse rate, sweat output and dermatological status of two groups of subjects, one wearing a protective uniform of Hycar Absorbent Protective Underwear and XXCC3 Impregnated Fatigues and the other standard long underwear and fatigue uniform were contrasted while the subjects engaged in various types of physical activity in a hot dry climate. There was no difference between the groups.

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